PROGRAMMED INSTRUCTION

HEAT

AB-2-2-15

Naval Air Technical Training Command

CNATT-M575 (Rev. 5-71) PAT

OBJECTIVES

AB-2-2-15--Heat

The student will:

1. Define heat. (1)
2. Select the definition of temperature. (2)
3. List six sources of heat. (4-10)
4. Match units of heat measurement with their definitions. (12-15)
5. Label the temperatures of the boiling, freezing, and absolute-zero points on a Fahrenheit thermometer scale. (22)
6. Label the temperatures of the boiling, freezing, and absolute-zero points on a centigrade thermometer scale. (23)
7. Label the temperatures of the boiling, freezing, and absolute-zero points on a Kelvin thermometer scale. (25)
8. Convert a Fahrenheit temperature to its equivalent centigrade temperature. (27)
9. Convert a centigrade temperature to its equivalent Fahrenheit temperature. (30)
10. Match the terms ''conduction,'' ''convection,'' and ''radiation'' with their definitions. (39-41)
11. Select the definition of heat capacity. (42)
12. Define specific heat. (44)
13. Solve for the amount of heat needed to produce a given temperature change in a quantity of water. (46)
14. Define coefficient of linear expansion. (54)
15. Select the definition of coefficient of volume expansion. (55)

16. Label the changes of state of matter indicated on a block diagram. (57)

17. Select the definition of equilibrium vapor pressure. (59)

SUGGESTED READING TIME 73 MINUTES

	1. **HEAT** is defined as thermal energy in the PROCESS OF TRANSFER between an object and its surroundings as a result of temperature difference. According to the kinetic theory of matter, the individual molecules, of which all matter is made, are in a state of rapid motion. Each molecule in a body possesses a certain amount of heat that causes motion. This molecular motion is called thermal energy. As a body is heated, the amount of thermal energy is increased; as a body is cooled, the amount of thermal energy is decreased. An object which has a high level of thermal energy can readily transfer that energy to an object with a lower level of thermal energy. Heat is _____ energy in the process of _____ between an object and its surroundings as a result of temperature difference.
thermal transfer	2. Heat and temperature, although not the same thing, are related. Heat is thermal energy in the process of transfer between a body and its surroundings as a result of a temperature difference. TEMPERATURE is a MEASURE OF THE ABILITY of a material to give up heat to, or absorb heat from, other materials. The greater the amount of thermal energy that an object possesses, the greater is its ability to transfer that energy,

	2. (Continued) and, consequently, the higher is its temperature. Temperature is a measure of the ability of a material to _____ _____ heat to, or _____ heat from, other materials.
give up absorb	3. Select the definition of heat. a. Heat is thermal energy in the process of transfer between an object and its surroundings as a result of temperature difference. b. Heat is kinetic energy in the process of temperature equalization between an object and its surroundings. c. Heat is a measure of the ability of a material to give up heat to, or absorb heat from, other materials. d. Heat is the molecular motion, or the thermal energy, of a material.
a.	4. Because heat is a form of energy, most heat sources are methods of converting other forms of energy into heat. The six most important sources of heat are: (1) The sun. (2) The earth's interior. (3) Chemical action. (4) Mechanical energy. (5) Electric energy. (6) Nuclear energy.

	4. (Continued) Most heat sources are methods of _____ other forms of energy into _____.
converting heat	5. The SUN is the most important of all heat sources. Either directly or indirectly, nearly all forms of heat may be traced to the sun. The heat from the sun provides an environment suitable for human habitation. The conversion of solar energy into electrical energy is likely to be the basis upon which the pollution-free society of the future will be founded. The most important source of heat is the _____.
sun	6. The EARTH'S INTERIOR is another source of heat. Two examples of heat from the earth's interior are molten lava from volcanoes and the boiling water from geysers. Two common sources of heat are the _____ and the _____ _____.

sun earth's interior	7. When a material is burned, it reacts chemically with oxygen to produce heat. The production of heat by CHEMICAL ACTION is probably the most frequently used source of heat over which man has control. Burning of fuels such as gas, oil, coal, and wood are prime examples of heat produced by chemical action. Another good example is the bodily function of food conversion. Oxygen unites chemically with food substances inside the body and provides heat to maintain the body temperature. Three common sources of heat are the sun, the _____ _____, and _____ _____.
earth's interior chemical action	8. MECHANICAL ENERGY is another source of heat. The energy that is used to overcome friction appears as heat. For example, when an automobile brake is used to slow the motion of an automobile, a sufficient amount of heat is generated to cause the external housing of the brake mechanism to become hot to the touch. List four sources of heat. (1) (2) (3) (4)

Sun. Earth's interior. Chemical action. Mechanical energy.	9. ELECTRIC ENERGY is another common source of heat. Heat is produced from electric energy by a resistance to current flow. Electric irons, toasters, ovens, and heaters are examples of the use of electric energy as a source of heat. List five sources of heat. (1) (2) (3) (4) (5)
Sun. Earth's interior. Chemical action. Mechanical energy. Electric energy.	10. Of all the sources of heat, NUCLEAR ENERGY promises to be the most important source of large amounts of energy. Large quantities of heat are produced by the process of nuclear fission. One kilogram of uranium, when it is utilized in fission reactions, is capable of producing as much heat as 3,000,000 kilograms of coal or 12,000,000 kilograms of oil. List six sources of heat. (1) (2) (3) (4) (5) (6)

Sun. Earth's interior. Chemical action. Mechanical energy. Electric energy. Nuclear energy.	11. Select the definition of temperature. a. Temperature is a measure of the ability of a material to generate heat from contact with another material. b. Temperature is a measure of the absorption or radiation of heat by a material over a period of time. c. Temperature is a measure of the ability of a material to give up heat to, or absorb heat from, other materials. d. Temperature is a measure of the ability of a material to contain heat.
c.	12. There are three units of heat measurement: (1) The British thermal unit (B.t.u.). (2) The calorie. (3) The Calorie. Two of these units, the B.t.u. and the calorie, are basic units of measurement. The third unit, the Calorie, is treated as a separate unit of measurement because of its frequent usage. Three units of heat measurement are the _____, the _____, and the _____.
B.t.u. calorie Calorie	13. The British thermal unit (B.t.u.) is the unit of heat measurement in the English, or foot-pound-second (fps), system of measurement. One B.t.u. is the quantity of heat needed to raise the temperature of one POUND of water one Fahrenheit degree.

	13. (Continued) The B.t.u. is used in both engineering and industry. One B.t.u. is the quantity of heat needed to raise the temperature of _____ _____of water _____ Fahrenheit degree.
one pound one	14. The calorie is the unit of heat measurement in the metric system of measurement and is used predominantly by research scientists. One calorie is defined as the quantity of heat needed to raise the temperature of one GRAM of water one centigrade degree. One calorie is the quantity of heat needed to raise the temperature of _____ _____ of water _____ centigrade degree.
one gram one	15. The Calorie is also a unit of heat measurement in the metric system. The Calorie is the equivalent of 1,000 calories (1 kilocalorie). One Calorie is defined as the quantity of heat needed to raise the temperature of one KILOGRAM of water one centigrade degree.

15. (Continued)

Match the units of measurement listed in column A with their definitions in column B.

A		B
___ (1) One B.t.u.	a.	The quantity of heat needed to raise the temperature of one gram of water one centigrade degree.
___ (2) One calorie.	b.	The quantity of heat needed to raise the temperature of one kilogram of water one centigrade degree.
___ (3) One Calorie.	c.	The quantity of heat needed to raise the temperature of one pound of water one Fahrenheit degree.

(1) c.

(2) a.

(3) b.

16. List six sources of heat.

(1)

(2)

(3)

(4)

(5)

(6)

Sun. Earth's interior. Chemical action. Mechanical energy. Electric energy. Nuclear energy.	17. Define heat.
Thermal energy in the process of transfer between an object and its surroundings as a result of temperature change.	18. Match the units of heat measurement in column A with their definitions in column B. A — B ____ (1) One B.t.u. — a. The quantity of heat needed to raise the temperature of one pound of water one Fahrenheit degree. ____ (2) One calorie. — b. The quant ty of heat needed to raise the temperature of one kilogram of water one centigrade degree. ____ (3) One Calorie. — c. The quant ty of heat needed to raise the temperature of one gram of water one centigrade degree.

(1) a. (2) c. (3) b.	19. Select the definition of temperature. a. Temperature is a measure of the ability of a material to contain heat. b. Temperature is a measure of the ability of a material to give up heat to, or absorb heat from, other materials. c. Temperature is a measure of the ability of a material to generate heat from contact with another material. d. Temperature is a measure of the absorption or radiation of heat by a material over a period of time.
b.	20. List six sources of heat. (1) (2) (3) (4) (5) (6)

Sun.

Earth's interior.

Chemical action.

Mechanical energy.

Electric energy.

Nuclear energy.

21. Match the units of heat measurement listed in column A with their definitions in column B.

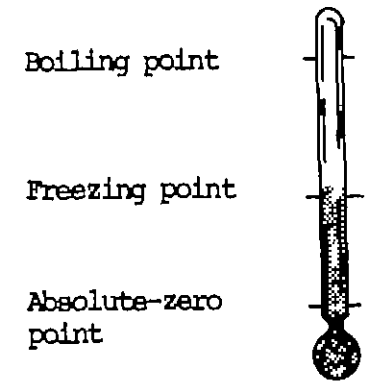
A	B
____ (1) One B.t.u.	a. The quantity of heat needed to raise the temperature of one kilogram of water one centigrade degree.
____ (2) One calorie.	b. The quantity of heat needed to raise the temperature of one kilogram of water one Fahrenheit degree.
____ (3) One Calorie.	c. The quantity of heat needed to raise the temperature of one gram of water one centigrade degree.
	d. The quantity of heat needed to raise the temperature of one pound of water one Fahrenheit degree.
	e. The quantity of heat needed to raise the temperature of one pound of water one centigrade degree.

(1) d.

(2) c.

(3) a.

22. Thermometry is the measurement of temperature as compared to a given standard. The Fahrenheit scale is used in the English, or foot-pound-second (fps), system of measurement. On the Fahrenheit scale shown below, the standard used is water with a boiling point of 212° F., a freezing point of 32° F., and an absolute-zero point of -460° F. The absolute-zero point is that point at which molecular energy is at a minimum.



Match the reference points listed in column A with the corresponding Fahrenheit temperatures in column B.

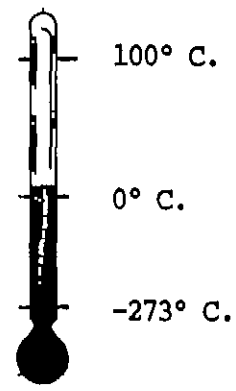
A	B
___ (1) Boiling point.	a. 0° F.
___ (2) Freezing point.	b. -32° F.
___ (3) Absolute-zero point.	c. -460° F.
	d. 212° F.
	e. 32° F.

(1) d.

(2) e.

(3) c.

23. The centigrade scale (also called the Celsius scale), abbreviated C., uses water as its standard with a boiling point of 100° C., a freezing point of 0° C., and an absolute-zero point of -273° C., as shown below.



Match the reference points listed in column A with the corresponding centigrade temperatures in column B.

A	B
____ (1) Boiling point.	a. 0° C.
____ (2) Freezing point.	b. 273° C.
____ (3) Absolute-zero point.	c. 100° C.
	d. -100° C.
	e. -273° C.

(1) c.

(2) a.

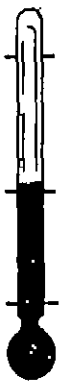
(3) e.

24. Label the temperatures of the boiling, freezing, and absolute-zero points on the Fahrenheit thermometer below.

Boiling point — a. _____ F.

Freezing point — b. _____ F.

Absolute-zero point — c. _____ F.



a. 212°

b. 32°

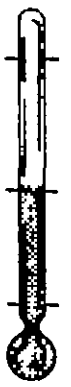
c. -460°

25. The Kelvin scale is based on a reference of ABSOLUTE ZERO and is generally used for scientific measurements. The Kelvin degree and the centigrade degree are the same unit of measurement. The major difference between these two scales is the point of zero reference.

The zero point on the Kelvin scale (0° K.) is absolute zero.

25. (Continued)

As shown below, water freezes at 273° K. and boils at 373° K.



The Rankine scale has the same relationship to the Fahrenheit scale that the Kelvin scale has to the centigrade scale. The Rankine degree and the Fahrenheit degree are the same unit of measurement. The difference between these two scales is the point of zero reference.

Match the reference points listed in column A with the corresponding Kelvin temperatures in column B.

A	B
____ (1) Boiling point.	a. 0° K.
____ (2) Freezing point.	b. -273° K.
____ (3) Absolute-zero point.	c. 273° K.
	d. 373° K.
	e. -32° K.

(1) d.

(2) c.

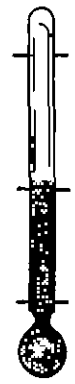
(3) a.

26. Label the temperatures of the boiling, freezing, and absolute-zero points on the centigrade thermometer below.

Boiling point — a. _____ C.

Freezing point — b. _____ C.

Absolute-zero point — c. _____ C.



a. 100°

b. 0°

c. -273°

27. To convert a Fahrenheit temperature reading to a centigrade temperature, the following formula is used:

$$T_C = \frac{5}{9} (T_F - 32)$$

where T_C = the centigrade temperature

T_F = the Fahrenheit temperature

To convert a temperature of 47° F. to an equivalent centigrade temperature, the following procedure is used:

$$T_C = \frac{5}{9} (T_F - 32)$$

Substitute: $T_C = \frac{5}{9} (47 - 32)$

Simplify: $T_C = \frac{5}{9} (15)$

Multiply: $T_C = 8.33°$ C.

	27. (Continued) Convert 72° F. to the equivalent centigrade temperature.
22.22° C.	28. Label the temperatures of the boiling, freezing, and absolute-zero points on the Kelvin thermometer below. Boiling point a. _____ K. Freezing point b. _____ K. Absolute-zero point c. _____ K. 

a. 373°

b. 273°

c. 0°

29. Label the temperatures of the boiling, freezing, and absolute-zero points on the Fahrenheit thermometer below.

Boiling point a. _____ F.

Freezing point b. _____ F.

Absolute-zero point c. _____ F.

a. 212°

b. 32°

c. -460°

30. The conversion from a centigrade temperature to an equivalent Fahrenheit temperature is accomplished by virtually the same process as the conversion from a Fahrenheit to a centigrade temperature.

$$T_C = \frac{5}{9} (T_F - 32)$$

Therefore,

$$T_F = \frac{9}{5} T_C + 32$$

where T_F = the Fahrenheit temperature

T_C = the centigrade temperature

To convert a temperature of 15° C. to an equivalent Fahrenheit temperature, the following procedure is used:

$$T_F = \frac{9}{5} T_C + 32$$

Substitute: $T_F = \frac{9}{5} (15) + 32$

Multiply: $T_F = 27 + 32$

Add: $T_F = 59°$ F.

	30. (Continued) Convert 50° C. to the equivalent Fahrenheit temperature.
122° F.	31. Which of the following centigrade temperatures is equivalent to 45° F.? a. 138.6° C. b. 7.2° C. c. 23.4° C. d. 42.7° C.

b.	32. Label the temperatures of the boiling, freezing, and absolute-zero points on the centigrade thermometer below. Boiling point a. _____ C. Freezing point b. _____ C. Absolute-zero point c. _____ C. 
a. 100° b. 0° c. -273°	33. Which of the following Fahrenheit temperatures is equivalent to 10° C.? a. 24.4° F. b. 122° F. c. 50° F. d. -14° F.

c.

34. Convert the following Fahrenheit temperature readings to equivalent centigrade temperatures.

a. 41° F. = _____ C.

b. 77° F. = _____ C.

c. 5° F. = _____ C.

a. 5°

b. 25°

c. -15°

35. Label the temperatures of the boiling, freezing, and absolute-zero points on the Kelvin thermometer below.

Boiling point a. _____ K.

Freezing point b. _____ K.

Absolute-zero point

a. 373° b. 273° c. 0°	36. Convert the following centigrade temperature readings to equivalent Fahrenheit temperatures. a. 20° C. = _____ F. b. 38° C. = _____ F. c. 47° C. = _____ F.
a. 68° b. 100.4° c. 116.6°	37. Convert the following Fahrenheit temperature readings to equivalent centigrade temperatures. a. 54° F. = _____ C. b. 14° F. = _____ C. c. 95° F. = _____ C.

a. 12.2°

b. -10°

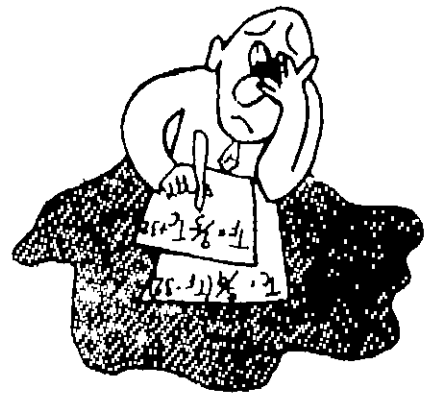
c. 35°

38. Convert the following centigrade temperature readings to equivalent Fahrenheit readings.

a. 90° C. = _____ F.

b. 55° C. = _____ F.

c. -15° C. = _____ F.



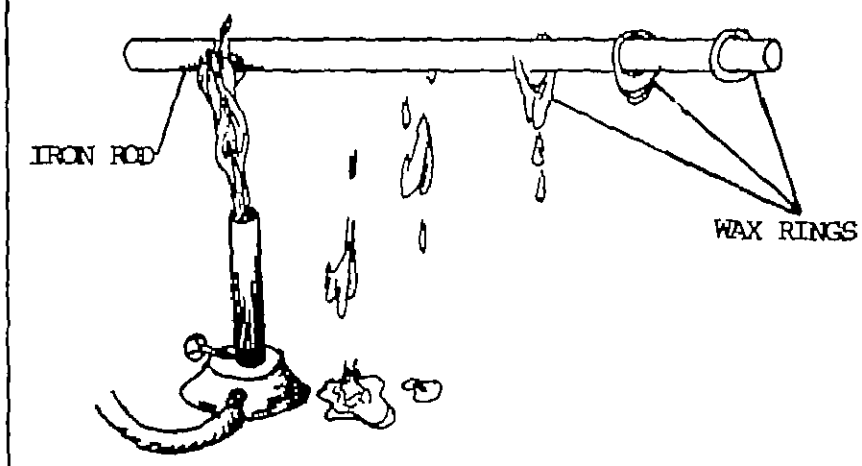
a. 194°

b. 131°

c. 5°

39. There are three methods by which heat is transferred from one location to another or from one body to another. They are CONDUCTION, CONVECTION, and RADIATION.

CONDUCTION is a method of heat distribution by which heat is transferred from molecule to molecule. Conduction occurs when one part of a body has a higher temperature than another part of the body. Heat is transferred from the part of a body which has the higher temperature to the part which has the lower temperature until the entire body is at the same temperature, as shown below.

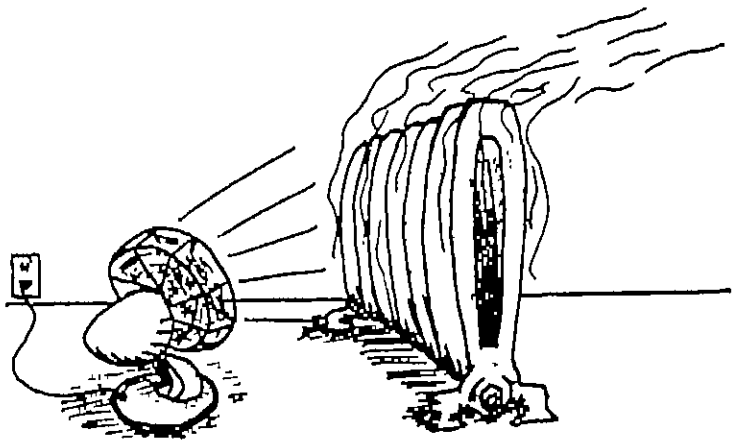


Conduction is the method of heat transfer by which heat is transferred from _____ to _____.

molecule

molecule

40. CONVECTION is the transfer of heat by the motion of a fluid. As a fluid is heated, it becomes less dense and rises. A cooler fluid is more dense and falls. When natural convection is not rapid enough to remove sufficient heat, fans or pumps can be used to accelerate the motion of the cooling medium, as illustrated below.



Convection is the transfer of heat by the _____ of a _____.

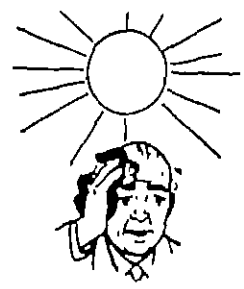
motion

fluid

41. Radiation is the transfer of heat by electromagnetic waves. Radiant-heat waves from the sun travel at the speed of light through the vacuum of outer space and through the earth's atmosphere. While conducted or convected heat travels by roundabout routes,

41. (Continued)

radiant heat travels in straight lines. Although radiant-heat waves travel through a vacuum with little difficulty, there are mediums and materials through which they cannot pass. When such a material is encountered, the radiant-heat wave is effectively cut off by either absorption or reflection.



Match the methods of heat transfer listed in column A with their definitions in column B.

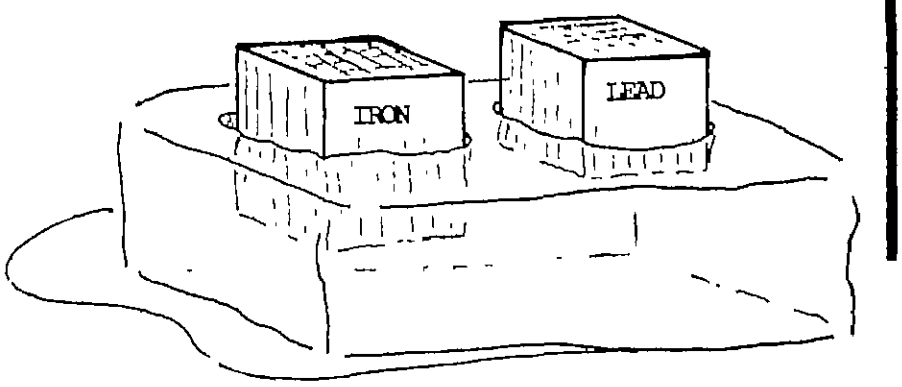
A	B
____ (1) Conduction.	a. Transfer of heat from molecule to molecule.
____ (2) Convection.	b. Transfer of heat by motion of a fluid.
____ (3) Radiation.	c. Transfer of heat by electron flow.
	d. Transfer of heat by electromagnetic waves.
	e. Transfer of heat by mechanical motion.

(1) a.

(2) b.

(3) d.

42. The HEAT CAPACITY of a material is the quantity of heat needed to raise its temperature one degree. Two materials, equal in weight and at the same temperature, will absorb or give out different amounts of heat because of differences in mass between two materials. For example, 5 pounds of lead and 5 pounds of iron are heated to a temperature of 70° C. and then placed on a block of ice. The figure below shows that the iron melts the ice to a greater depth.



The iron has melted more of the ice than the lead because the iron has a greater heat capacity than the lead.

The heat capacity of a material is the _____ of _____ that is needed to raise its temperature one degree.

quantity

heat

43. Match each term in column A with its definition in column B.

A	B
____ (1) Conduction.	a. Transfer of heat by electron flow.
____ (2) Convection.	b. Transfer of heat by electromagnetic waves.
____ (3) Radiation.	c. Transfer of heat by the motion of a fluid.
	d. Transfer of heat from molecule to molecule.
	e. Transfer of heat by mechanical motion.

(1) d.

(2) c.

(3) b.

44. SPECIFIC HEAT is the heat capacity of a material per unit mass. Specific heat differs from heat capacity in that it is a characteristic of the type of material and does not vary among different samples of a material. The values of specific heat for several materials are listed in the chart below.

MATERIAL	SPECIFIC HEAT
Brass	0.0917
Copper	0.0924
Iron	0.1075
Lead	0.0305
Tungsten	0.0372
Water	1.0000
Ice	0.5300
Zinc	0.0922

The figures shown above represent the specific heat rating for 1 gram of each of the materials. If more than 1 gram (unit) of a substance is involved, heat capacity is calculated by multiplying the specific heat of the substance by the number of units involved.

The heat capacity of a material per unit mass is _____ _____.

specific heat	45. Select the definition of heat capacity. a. The heat capacity of a material is the maximum amount of heat that a material can contain without changing its temperature. b. The heat capacity of a material is the maximum amount of heat that the material can absorb. c. The heat capacity of a material is the quantity of heat that is needed to raise its temperature one degree. d. The heat capacity of a material is the quantity of heat that is needed to raise the temperature of one gram of the material one degree.
c.	46. When the specific heat of the material is known, the quantity of heat necessary to produce a given temperature change can be readily calculated by the use of the formula $Q = m\ c\ \Delta T$ where Q = the quantity of heat m = the mass of weight c = the specific heat ΔT = the change in temperature Specific heat is a constant determined by the material. The specific heat of WATER is 1, regardless of which system of measurement (English or metric) is used.

46. (Continued)

To solve for the quantity of heat necessary to raise the temperature of 3 pounds of water six Fahrenheit degrees, use the formula

$$Q = m\ c\ \Delta T$$
$$= (3) \times (1) \times (6)$$
$$= 18 \text{ B.t.u.}$$

To solve for the quantity of heat necessary to raise the temperature of 5 grams of water two centigrade degrees, use the formula

$$Q = m\ c\ \Delta T$$
$$= (5) \times (1) \times (2)$$
$$= 10 \text{ calories}$$

To solve for the quantity of heat necessary to raise the temperature of 7 kilograms of water one centigrade degree, use the formula

$$Q = m\ c\ \Delta T$$
$$= (7) \times (1) \times (1)$$
$$= 7 \text{ Calories}$$

To raise the temperature of 10 pounds of water one Fahrenheit degree would require _____ B.t.u.

10	47. Select the definition of specific heat. a. The specific heat of a material is the quantity of heat needed to raise its temperature one degree. b. The specific heat of a material is its heat capacity per unit mass. c. The specific heat of a material is always equal to one. d. The specific heat of a material is the maximum amount of heat that the material can absorb.
b.	48. Match each term in column A with its definition in column B. A — B ____ (1) Conduction. a. Transfer of heat from molecule to molecule. ____ (2) Convection. b. Transfer of heat by electromagnetic waves. ____ (3) Radiation. c. Transfer of heat by electron flow. d. Transfer of heat by motion of a fluid. e. Transfer of heat by mechanical motion.
(1) a. (2) d. (3) b.	49. To raise the temperature of 5 grams of water one centigrade degree would require _____ calories.

5	50. Select the definition of heat capacity. a. The heat capacity of a material is the quantity of heat that is needed to raise its temperature one degree. b. The heat capacity of a material is the maximum amount of heat that the material can contain. c. The heat capacity of a material is the maximum amount of heat that a material can contain without changing its temperature. d. The heat capacity of a material is the quantity of heat that is needed to raise the temperature of one gram of the material one degree.
a.	51. Solve for the quantity of heat needed to produce the following temperature changes in water: a. Fifty kilograms of water 10 centigrade degrees. b. Four pounds of water 15 Fahrenheit degrees. c. Twelve grams of water five centigrade degrees.
a. 500 Cal. b. 60 B.t.u. c. 60 cal.	52. Define specific heat.

The heat capacity of a material per unit mass.	53. Solve for the quantity of heat needed to produce the following temperature changes in water: a. Twenty pounds of water one Fahrenheit degree. b. Five pounds of water 10 Fahrenheit degrees. c. Ten grams of water 30 centigrade degrees.
a. 20 B.t.u. b. 50 B.t.u. c. 300 cal.	54. With few exceptions, matter expands when heated and contracts when cooled. Different materials of the same length expand different amounts for the same increase in temperature. Linear expansion of matter is primarily concerned with solids, since liquids and gases have no shapes of their own. The amount of change in length of a heated solid can be predetermined by its coefficient of linear expansion. The COEFFICIENT OF LINEAR EXPANSION is defined as the change in unit length of a solid when its temperature is changed one degree. The change in length of a heated solid is equal to the product of its original length, its change in temperature, and its coefficient of linear expansion (α). This may be expressed by the formula:

54. (Continued)

$$\Delta L = \alpha L (T - T_o)$$

Coefficient of linear expansion is defined as the change in unit _____ of a solid when its _____ is changed one _____.

length
temperature
degree

55. The COEFFICIENT OF VOLUME EXPANSION is the change in a unit of volume per degree of change in temperature. For most solids, the coefficient of volume expansion is approximately three times the coefficient of linear expansion. Nearly all gases have approximately the same coefficient of volume expansion, which is nearly constant except for temperatures near the liquefying point.

The change in the volume of a heated gas is equal to the product of its coefficient of volume expansion (β), its original volume, and its change in temperature. This may be expressed by the formula:

$$\Delta V = \beta V (T - T_o)$$

The coefficient of volume expansion is the change in a _____ _____ per degree of change in _____.

unit
volume

temperature

56. Select the definition of coefficient of linear expansion.

a. Coefficient of linear expansion is the change in the unit volume of a solid per degree of temperature change.

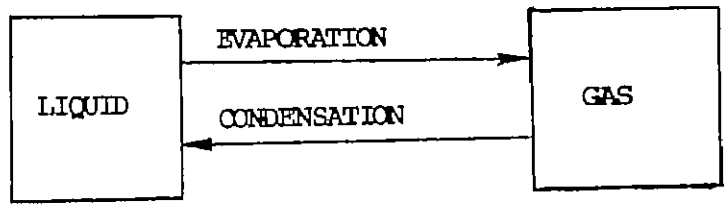
b. Coefficient of linear expansion is the change in the unit length of a solid per degree of temperature change.

c. Coefficient of linear expansion is the unit length of a solid per degree of temperature.

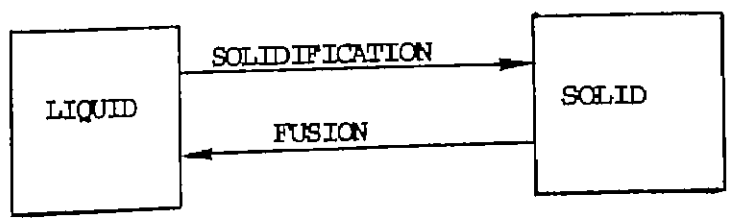
d. Coefficient of linear expansion is the unit volume of a gas per degree of temperature.

b.

57. Matter can exist in one of three states: gas, liquid, or solid. Water is most often used to explain the change of state process, but bear in mind that any matter will undergo a change of state with a sufficient change in temperature. The diagram below illustrates that as water boils, it changes from a liquid state to a gaseous state (steam) by a process known as EVAPORATION. When heat is removed, this gas (steam) returns to the liquid by the process of CONDENSATION.

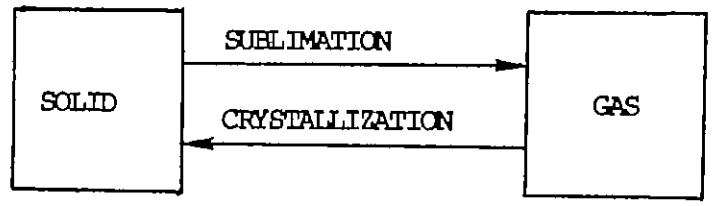


As heat is removed, water undergoes a change from a liquid state to a solid state (ice) by the process called SOLIDIFICATION. When heat is added, a solid (ice) returns to the liquid state by the process known as FUSION, as shown below.



57. (Continued)

Some solids, when heated, change directly to a gas without passing through the liquid state by means of the process of SUBLIMATION. A gas which becomes a solid when cooled without going through the liquid state undergoes the process of CRYSTALLIZATION, as shown below.



a. When a liquid changes to a gas, it undergoes evaporation; and when a gas changes to a liquid, it undergoes _____.

b. The change of a solid to a gas is the process of sublimation; the change of a gas directly to a solid is _____.

c. The change of a liquid to a solid is solidification; the change of a solid to a liquid is _____.

a. condensation b. crystallization c. fusion	58. Select the definition of coefficient of volume expansion. a. Coefficient of volume expansion is the change in unit length of a solid when its temperature is changed one degree. b. Coefficient of volume expansion is the change in a unit volume per degree of change in temperature. c. Coefficient of volume expansion is the change in unit length per unit volume of a solid and is independent of changes in temperature. d. Coefficient of volume expansion is the total change in the volume of a material over the average temperature range.
b.	59. EQUILIBRIUM VAPOR PRESSURE is the pressure exerted by vapor molecules of a substance when evaporation and condensation rates are equal. When the vapor of a liquid is condensing at the same rate that the liquid is evaporating, the liquid is in a state of equilibrium. At equilibrium, no change in the volume of the liquid occurs, because for every molecule of liquid that changes to a gaseous state there is a vapor molecule which changes to the liquid state. If water is boiled in an open pan, it evaporates completely in a relatively short time. Water can be boiled for several hours in a pressure cooker, because the rate of condensation and the rate of evaporation become equal, setting up a state of equilibrium. In a state of equilibrium, one additional force, or pressure, is exerted upon the surface of a liquid, the pressure exerted by vapor molecules as they condense. This

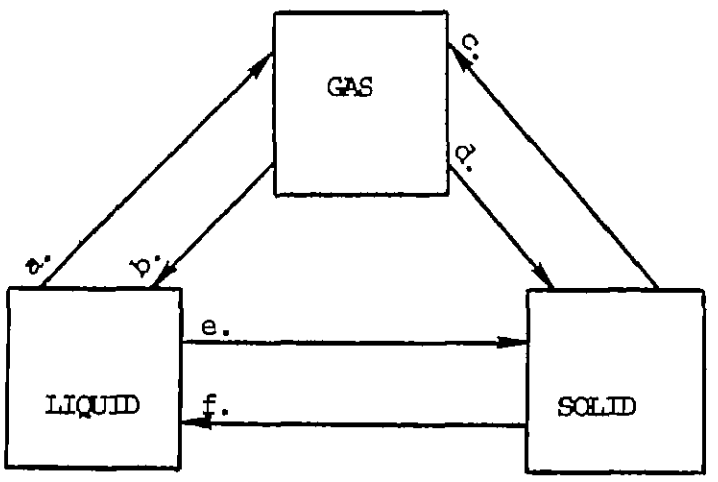
59. (Continued)

equilibrium vapor pressure is in opposition to the process of evaporation and is part of the explanation of the performance of the pressure cooker.

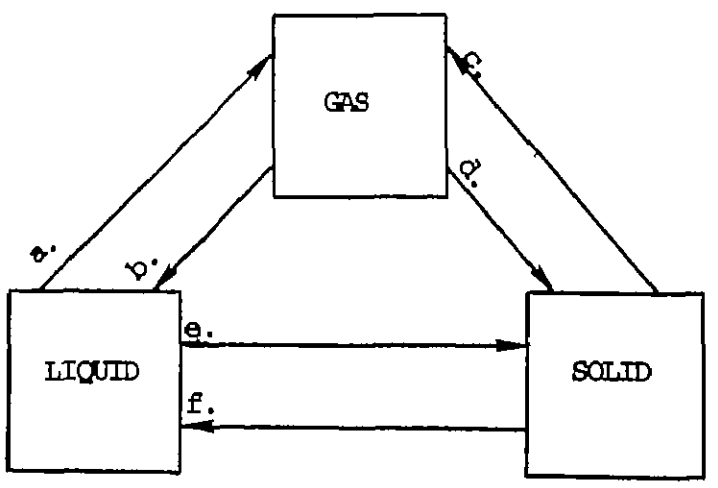
The pressure exerted by the vapor molecule of a substance upon that substance when its rate of condensation and evaporation are equal is _____ _____ _____.

equilibrium vapor pressure

60. On the block diagram below, label the changes of state.



a. Evaporation b. Condensation c. Sublimation d. Crystallization e. Solidification f. Fusion	61. Define coefficient of linear expansion.
The change in the unit length of a solid when its temperature is changed one degree.	62. Select the definition of equilibrium vapor pressure. a. Equilibrium vapor pressure is the total pressure exerted upon the surface of a substance when its rate of sublimation and its rate of crystallization are equal. b. Equilibrium vapor pressure is the algebraic sum of the atmospheric pressure and evaporation pressure. c. Equilibrium vapor pressure is the pressure exerted by vapor molecules of a substance when evaporation and condensation rates are equal. d. Equilibrium vapor pressure is the total pressure exerted upon the surface of a substance when its rate of condensation equals its rate of evaporation.

c.	63. Select the definition of coefficient of volume expansion. a. Coefficient of volume expansion is the change in unit length of a solid when its temperature is changed one degree. b. Coefficient of volume expansion is the change in a unit volume per degree of change in temperature. c. Coefficient of volume expansion is the change in unit length per unit volume of a solid and is independent of changes in temperature. d. Coefficient of volume expansion is the total change in the volume of a material over the average temperature range.
b.	64. On the block diagram below, label the changes of state. 

a. Evaporation b. Condensation c. Sublimation d. Crystallization e. Solidification f. Fusion	65. Select the definition of equilibrium vapor pressure. a. Equilibrium vapor pressure is the pressure exerted by vapor molecules of a substance when condensation and evaporation rates are equal. b. Equilibrium vapor pressure is the total pressure exerted upon the surface of a substance when its rate of condensation equals its rate of evaporation. c. Equilibrium vapor pressure is the algebraic sum of the atmospheric pressure and vapor pressure. d. Equilibrium vapor pressure is the total pressure exerted upon the surface of a substance when its rate of sublimation and its rate of crystallization are equal.
a.	

You have completed this program. Review the objectives on page i. If you do not completely understand an objective, refer to the frame/s indicated in parentheses.

REFERENCES:

1. Dull, Charles E., H. Clark Metcalfe, and John E. Williams. Modern Physics. New York: Holt, Rinehart, and Winston, 1968. Chapters 7, 8, and 9, pages 141-206.

2. Harris and Hemmerling. Introductory Applied Physics. New York: McGraw-Hill, 1965. Chapters 12, 13, 14, and 15, pages 212-336.

REVIEW TEST

AB-2-2-15--Heat

1. Define heat.

2. Select the definition of temperature.

   a. Temperature is a measure of the ability of a material to give up heat to, or absorb heat from, other materials.

   b. Temperature is a measure of the ability of a material to contain heat.

   c. Temperature is a measure of the absorption or radiation of heat by a material over a period of time.

   d. Temperature is a measure of the ability of a material to generate heat from contact with another material.

3. List six sources of heat.

   (1)

   (2)

   (3)

   (4)

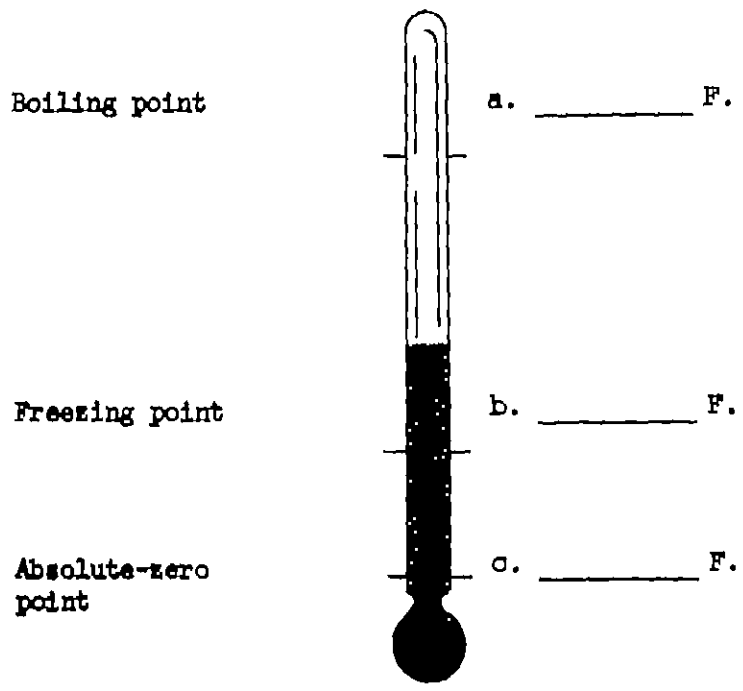
   (5)

   (6)

4. Match the units of heat measurement in column A with their definitions in column B.

A	B
____ (1) One B.t.u.	a. The quantity of heat needed to raise the temperature of one kilogram of water one centigrade degree.
____ (2) One calorie.	b. The quantity of heat needed to raise the temperature of one pound of water one Fahrenheit degree.
____ (3) One Calorie.	c. The quantity of heat needed to raise the temperature of one gram of water one centigrade degree.
	d. The quantity of heat needed to raise the temperature of 10 kilograms of water one Fahrenheit degree.
	e. The quantity of heat needed to raise the temperature of one pound of water 10 centigrade degrees.

5. Label the temperatures of the boiling, freezing, and absolute-zero points on the Fahrenheit thermometer below.

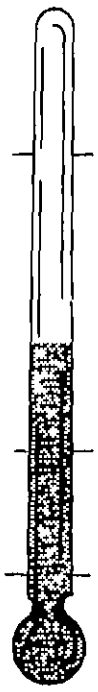


6. Label the temperatures of the boiling, freezing, and absolute-zero points on the centigrade thermometer below.

Boiling point

Freezing point

Absolute-zero point



a. _____ C.

b. _____ C.

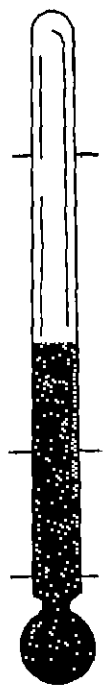
c. _____ C.

7. Label the temperatures of the boiling, freezing, and absolute-zero points on the Kelvin thermometer below.

Boiling point

Freezing point

Absolute-zero point



a. _____ K.

b. _____ K.

c. _____ K.

8. Convert 42° Fahrenheit to its equivalent centigrade temperature.

9. Convert 15° centigrade to its equivalent Fahrenheit temperature.

10. Match each term in column A with its definition in column B.

A	B
____ (1) Conduction.	a. Transfer of heat by electron flow.
____ (2) Convection.	b. Transfer of heat by the motion of a fluid.
____ (3) Radiation.	c. Transfer of heat from molecule to molecule.
	d. Transfer of heat by electromagnetic waves.
	e. Transfer of heat by mechanical motion.

11. Select the definition of heat capacity.

    a. The heat capacity of a material is the quantity of heat that is needed to raise the temperature of one gram of the material one degree.

    b. The heat capacity of a material is the maximum amount of heat that the material can contain.

    c. The heat capacity of a material is the quantity of heat that is needed to raise its temperature one degree.

    d. The heat capacity of a material is the maximum amount of heat that a material can contain without changing its temperature.

12. Define specific heat.

13. Solve for the quantity of heat necessary to raise the temperature of 10 pounds of water two Fahrenheit degrees.

14. Define coefficient of linear expansion.

15. Select the definition of coefficient of volume expansion.

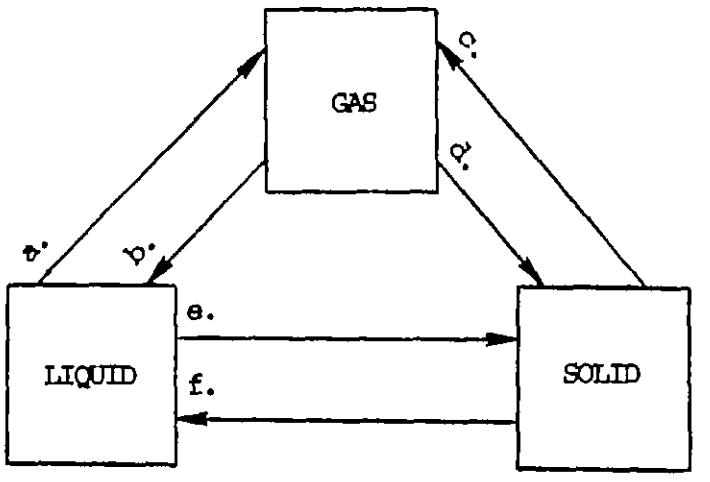
    a. Coefficient of volume expansion is the change in unit length of a solid when its temperature is changed one degree.

    b. Coefficient of volume expansion is the change in a unit volume per degree of change in temperature.

    c. Coefficient of volume expansion is the change in unit length per unit volume of a solid and is independent of changes in temperature.

    d. Coefficient of volume expansion is the total change in the volume of a material over the average temperature range.

16. On the block diagram below, label the changes of state.



17. Select the definition of equilibrium vapor pressure.

a. Equilibrium vapor pressure is the pressure exerted by vapor molecules of a substance when evaporation and condensation rates are equal.

b. Equilibrium vapor pressure is the total pressure exerted upon the surface of a substance when its rate of condensation equals its rate of evaporation.

c. Equilibrium vapor pressure is the algebraic sum of the atmospheric pressure and evaporation pressure.

d. Equilibrium vapor pressure is the total pressure exerted upon the surface of a substance when its rate of sublimation and its rate of crystallization are equal.

ANSWERS TO REVIEW TEST

AB-2-2-15--Heat

1. Thermal energy in the process of transfer between an object and its surroundings as a result of temperature change.

2. a.

3. Sun.
   Earth's interior.
   Chemical action.
   Mechanical energy.
   Electric energy.
   Nuclear energy.

4. (1) b.
   (2) c.
   (3) a.

5. a. 212° F.
   b. 32° F.
   c. -460° F.

6. a. 100° C.
   b. 0° C.
   c. -273° C.

7. a. 373° K.
   b. 273° K.
   c. 0° K.

8. 5.5° C.

9. 59° F.

10. (1) c.
    (2) b.
    (3) d.

11. c.

12. The heat capacity of a material per unit mass.

13. 20 B.t.u.

14. The change in the unit length of a solid when its temperature is changed one degree.

15. b.

16. a. Evaporation
    b. Condensation
    c. Sublimation
    d. Crystallization
    e. Solidification
    f. Fusion

17. a.

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